Background

The 2013 Record of Decision Amendment includes enhanced bioremediation (EBR) "quote from RODA". The EPA-approved May 2014 RD/RA included an outline of how EBR would be implemented, which included 61 injection and extraction wells to distribute the terminal electron acceptor (TEA) during 1.5 to 3 years of recirculation, which would also provide containment of the contaminant plume. Modeling had been used by AMEC to determine that the well spacing should be no greater than 75 feet and that the pumping rate should be 160 gallons per minute (gpm). The TEA to be used had not been determined, but comparisons were provided between the use of aerobic biodegradation by supplying oxygen as peroxide, or the use of anaerobic biodegradation using sulfate.

July 2014 Field Test

Amec in July 2014 (before SEE implementation) conducted a field test of anaerobic biodegradation to provide field data to support the anaerobic EBR modeling that was performed as part of the ST012 RD/RAWP due to the fact that significant assumptions were made in the modeling analysis (Addendum #2, Appendix C, page 1-1; "Modeling results for both processes indicated that the remediation goals could be met; however, there were **significant assumptions made for the anaerobic approach.**" (emphasis added)). This field test was comprised of two push-pull tests performed at existing wells W-11 and W-30, both of which are completed in the lower saturated zone (LSZ), and both of which were known to be impacted by LNAPL. The purpose of the field test was to determine sulfate utilization rates. While microbial data collected during the field test showed increased populations of sulfate reducing bacteria, the data collected during the extraction phase could not be used to determine sulfate utilization rates. Pumping rates during the extraction phase from W-30 could not be sustained due to well fouling, and the limited amount of groundwater extracted from W-30 'did not provide a sufficient data set to estimate sulfate utilization' (lines 475-476). At W-11, sulfate concentrations increased during the pull portion of the test, which 'indicate that background groundwater sulfate concentrations were being pulled into the well and prevent the accurate estimation of sulfate utilization' (lines 477-478).

Instead, sulfate utilization was estimated from the shut-in portion of the test. Data presented from W-11 show that the TPH and benzene concentrations remained essentially constant during the shut in period (Table 2-1), while normalized sulfate concentrations were greater than the normalized tracer concentrations during most of the shut in phase of the test (Graph 3-4). Thus, very little sulfate utilization was demonstrated from the results at this well.

Data from W-30 show that the DRO and TPH concentrations increased substantially during the shut-in period of the test and benzene concentrations approximately doubled (Table 2-2), while the sulfate concentration decreased exponentially with time (Table 2-6). While the results at this well showed sulfate utilization during the shut in period (Graph 3-5), the results did not demonstrate that TPH or benzene were consumed by the sulfate that was utilized. After review of the field test report, EPA commented: "The results of the EBR Pilot Test are equivocal, difficult to interpret for practical use, and result in high uncertainty when used to model and plan full-scale EBR, and MNA." (CSS: *Review of Documents for Operable Unit 2, Site ST012, at the Former Williams Air Force Base, Mesa, AZ* May 17, 2016).

Commented [DE1]: Carolyn, I bet you have a good quote from the RODA we can use here

Commented [WU2]: In the ROD?

Commented [WU3]: Lines 156-158, p 1-1, Addendum #2 Remedial Design and Remedial Action Work Plan – Site ST012 Appendix C Enhanced Bioremediation Field Test Report

Commented [WU4]: Lines 475-476, p 3-4, Addendum #2 Remedial Design and Remedial Action Work Plan – Site ST012 Appendix C Enhanced Bioremediation Field Test Report

Commented [WU5]: Lines 477-478, p 3-4, Addendum #2 Remedial Design and Remedial Action Work Plan – Site ST012 Appendix C Enhanced Bioremediation Field Test Report

Commented [WU6]: p 2-3, Addendum #2 Remedial Design and Remedial Action Work Plan – Site ST012 Appendix C Enhanced Bioremediation Field Test Report

Commented [WU7]: p 3-5, Addendum #2 Remedial Design and Remedial Action Work Plan – Site ST012 Appendix C Enhanced Bioremediation Field Test Report

Commented [WU8]: p 2-4, Addendum #2 Remedial Design and Remedial Action Work Plan – Site ST012 Appendix C Enhanced Bioremediation Field Test Report

Commented [WU9]: p 2-7, Addendum #2 Remedial Design and Remedial Action Work Plan – Site ST012 Appendix C Enhanced Bioremediation Field Test Report

Commented [WU10]: p 3-6, Addendum #2 Remedial Design and Remedial Action Work Plan – Site ST012 Appendix C Enhanced Bioremediation Field Test Report

Addendum #2, which was first submitted to the Agencies for review in November 2015, proposes a very different approach for implementation of EBR than was contained in the May 2014 work plan. First, based on the field test, sulfate ~~is~~ was chosen as the TEA. Based on the fact that a very large amount of TEA ~~will~~ would be required, which would be difficult to provide via oxygen injection, the proposed use of sulfate appeared reasonable to EPA. However, AMEC's modeling performed at the conclusion of the Thermally Enhanced Extraction (TEE) pilot test indicated that while sulfate is depleted in the LSZ within the LNAPL plume, ~~it~~ sulfate is not depleted within the LNAPL plume in the upper water bearing zone (UWBZ) (BEM, 2010, Appendix M, see Figure M.5.1.2.4). Second, the amount of TEA ~~required~~ proposed by AMEC to be used was reduced from 7600 tons of sulfate to 840 tons. A third change was to significantly reduce the number of injection and extraction wells from 61 to 18. A fourth change was that instead of 1.5 – 3 years of recirculation and plume containment at a pumping rate of 160 gpm, it was proposed to perform limited pumping (i.e., no recirculation and only incidental containment) during the injection of a very high concentration of sulfate (320,000 mg/L), and then to allow diffusion and dispersion to distribute sulfate throughout the LNAPL plume over approximately a five year period (see Addendum #2, Appendix E).

Agency Concerns about EBR

Although it was the Agencies' understanding at the time the RODA was signed that the majority of the LNAPL would be recovered by SEE, and what was understood by AF and EPA to be minimal residual LNAPL and dissolved phase at the periphery of the SEE treatment area would be addressed with EBR. Thus, the Agencies believed that EBR would be implemented in the area surrounding the SEE treatment zone where moderate temperature increases might be expected to further enhance microbial growth and hydrocarbon degradation. SEE was expected to reduce the benzene concentrations within the treatment area to 100 – 500 ug/L, ~~and~~ which could then be transitioned directly to monitored natural attenuation (MNA). However, the actual SEE treatment zone included only approximately half of the LNAPL at ST12 (Final RD/RA Work Plan, May 2014). Also, according to estimates provided by Amec (February 2017 BCT meeting), Amec now states that approximately 200,000 gallons of LNAPL remain in the SEE treatment area, and another 2000,000+ gallons remains in the site periphery. Thus, there is considerably more mass remaining in the subsurface than what the Agencies had understood would be treated by EBR, and approximately half of that mass is in the still-extremely hot SEE treatment area, which is likely too hot to support native sulfate reducing microbes. Amec recognizes this fact, as the first step in ~~there~~ their implementation plan calls for stabilizing the temperature to no more than a 1°F increase per day before initiating EBR.

The Air Force has stated that they are committed to "achieving remedial action objectives within our ROD Amendment's estimated timeframe" (March 15, 2017 letter signed by Phil Mook). However, the Agencies have very significant concerns that the approach proposed in Addendum #2 will not only fail to meet the remedial goals within the remedial timeframe, but will actually make the contamination situation at ST12 worse by reducing contaminant degradation rates and allowing the contaminant plume to spread. These concerns are based on:

1) Site conditions in terms of the remaining LNAPL mass are different from those contemplated in the RODA for EBR/MNA (i.e., there appears to be much more LNAPL remaining than was expected by the Regulatory Agencies).

Commented [DE11]: Carolyn – is this correct?

Commented [WU12]: I may have misunderstood this. Are we saying that AMEC decided to choose sulfate (which they did, of course), or are we saying that EPA agreed that AMEC's choice of sulfate rather than oxygen appeared to be reasonable (which I did say)?

Maybe we could say "Based on the fact that a very large amount of TEA will would be required, which would be difficult to provide via oxygen injection, AMEC proposed to use sulfate as the TEA, which appeared reasonable to EPA." However, I'm not sure we should put our opinion here, since this section is basically a history of AF's changes in the EBR approach, and not a history of our opinions/comments.

Commented [WU13]: We use both TEE and SEE. Do we mean something different by these?

Commented [WU14]: We probably need a quote here.

Commented [WU15]: Maybe we should use "Agencies" all along in this document, or is there value to specifying EPA in some places?

Commented [WU16]: Need the reference.

2) EBR/MNA has not been tested and proven effective at a site of this size, complexity, and source mass – particularly in terms of the timeframe contemplated, so the proposed EBR application ~~must~~ should involve more extensive data collection and field testing before implementation of EBR at full scale.
3) The extremely high sulfate injection rate proposed in Addendum #2 would be a ‘shock loading’ of sulfate which could have a detrimental effect on the microbial populations that ~~they~~AF ~~are~~is trying to stimulate, due to the geochemical changes this highly concentrated sulfate addition will cause. The November 2016 response to comments on Addendum #2 (RTC) acknowledges that the high injection concentrations of sulfate will likely limit microbial growth ~~at~~ near the injection wells. The ST012 Decision Tree and Criteria for Enhanced Bioremediation “(Decision Tree)” for EBR provided on March 16, 2017 seems to indicate that sulfate concentrations must be below 30,000 mg/L to not cause inhibition. The conservative tracer transport model results presented in Appendix E Groundwater Model Outputs of Addendum #2 indicate that significant portions of the site will remain at concentrations of this level for as long as 1990 days (approximately 5.5 years) after sulfate injection. Suthersan et al. (2011) states, **“sulfate application strategies that employ repeat injections at highly elevated concentrations may not be as effective as sulfate delivery strategies that achieve relatively steady sulfate concentrations over time in the range of 100 to 2000 mg/L. This can increase the efficiency of the process while limiting the geochemical footprint of the reactions.”**
4) Research has shown that even when sulfate reducing microbes that can oxidize petroleum hydrocarbons are present, benzene reduction may not occur (ESTCP, 1999). It has not been demonstrated that sulfate-reducing bacteria that can degrade benzene are present at this site. Although it appears that benzene degradation is occurring, essentially all TEA (except CO_2) are depleted at this site (BEM, 2010), and thus, benzene degradation may be occurring via a different microbial population.
5) It is not clear that the UWBZ is deficient in sulfate (BEM, 2010), in which case sulfate addition will not stimulate hydrocarbon oxidation.
6) It is not clear that the proposed mass of sulfate to be injected – as large as it is – is sufficient to degrade the LNAPL mass that remains. Addendum #2, Lines 822-827: “Initial target TEA dosage is based on treating approximately 30% of the LNAPL mass in the CZ, UWBZ, and LSZ, on treating approximately 30% of the LNAPL mass in the CZ, UWBZ, and LSZ, accounting for the likelihood that BTEX+N will be preferentially consumed during bioremediation over longer chain hydrocarbons. **Although BTEX+N are the primary COCs, other compounds will degrade and consume sulfate in the process.”** (emphasis added). According to the referenced ESTCP document, “***Ground water contaminated from gasoline contains not only BTEX compounds, but many other gasoline components as well. At the Seal Beach site, much of the injected nitrate and sulfate was utilized by bacteria to degrade non-BTEX hydrocarbons. This makes it difficult to predict the amount of electron acceptor(s) that will be needed for complete BTEX removal.***” In field experiments at a gasoline spill site, Reinhard et al. (ES&T, 31(1):28-36, 1997) found that only 13 to 40% of the sulfate consumed was used to degrade BTEX.

Commented [WU17]: ST012_EBR_Decision_Matrix.pdf
ST012 Decision Tree and Criteria for Enhanced Bioremediation

Target Numerical Conditions

Decision Objective: To Establish Biological Degradation by Sulfate Reducing Bacteria (SRB) at ST012 and has been Enhanced

Time Frame: 3-9 months post injection

Criteria: Sulfate

Target Numerical Conditions: Non-Inhibiting
30000* [*30000 ppm dissolved sulfate in the groundwater*]

*Preliminary ranges for target sulfate concentrations in the formation. Values are subject to modification based on observation of SRB responses in the field to sulfate. Higher concentration may be present in the immediate vicinity of injection wells.

Commented [WU18]: For example,

Appendix E Groundwater Model Outputs

Figure E-21, Conservative Tracer Transport Model Results, Lower Saturated Zone - 220 Ft Bgs, 1990 Days From Tracer Injection

Commented [WU19]: Does this mean that oxygen, nitrate, manganese, sulfate, are BDL across the site – i.e., does “depleted” mean at lower than background levels, or entirely gone?

Commented [WU20]: DFP: I don’t think I have this **BEM 2010** document. What is the name of it?

Commented [WU21]: Does this mean the sulfate is at background levels, or only slightly below, or at least still in mg/L concentrations?

6)

7) Numerical modeling using MODFLOW-SURFACT was used to support the contention that 1.5 years of sulfate addition/recirculation could reduce benzene concentrations to levels that could then degrade over the next 15 years to via MNA to reach the cleanup goal of MCLs. However, as was discussed during the March 16, 2017 BCT conference call, the model likely overestimates the degradation rate due to the assumptions of equilibrium between the LNAPL and dissolved phases (i.e., no mass transfer limitations), and the use of an estimate of naturally occurring organic matter (foc) of 0.0003, which leads to too low of an estimate of contaminant sorption and retardation. Also, there was extensive discussion during this call where AMEC indicated that the modeling, as performed, is not predictive. That is, -Tthe modeling results can only legitimately be used as a tool to compare estimated time frames under differing scenarios, and not to predict actual timeframes for reaching remedial goals. ***Thus, the modeling that was performed cannot be interpreted as support for Amec's contention that the cleanup goals can be achieved in an estimated 20 years.***

8) Approximately one year after termination of steam injection, large portions of the SEE treatment area remain at temperatures that are likely not conducive to the natively-occurring microbial populations, although some of the less-impacted areas may be experiencing increases in microbial growth. Amec's mass estimates indicate that 200,000 gallons of LNAPL remain in ~~this~~ the SEE-treated ~~zone~~area, so it is particularly important that enhanced microbial degradation of BTEX+N be highly active in this high-temperature area if EBR is to be successful.

9) It is not clear that sulfate can be distributed throughout the site through the reduced number of injection wells. Using a push-pull method where the distance between the injection and extraction well varies from about 100 to nearly 250 feet is likely to result in the development of preferential flow pathways, particularly if high pumping rates are used in the extraction wells. As a result, the sulfate is likely to be distributed primarily along the preferential flow pathways and is not likely to be distributed across all of the areas where EBR is intended to treat LNAPL and dissolved phase contamination. Modeling is useless to evaluate whether the push-pull method can be used successfully; only actual field data can be used to evaluate this.

8)10) The apparent intent to treat only dissolved benzene is not likely to be successful because the LNAPL is a significant reservoir of benzene, which will continue to dissolve into groundwater for many years. Therefore, it is important to treat both LNAPL and dissolved-phase benzene. Further, encapsulation of LNAPL by microbial films (to degrade the BTEX moving from LNAPL to GW), by iron sulfide precipitates (to reduce flux of BTEX from LNAPL to GW), fouling and precipitates in and around LNAPL bodies (so that GW does not flow close to the LNAPL such that benzene is not readily be dissolved) could cause GW concentrations of BTEX to fall, while much BTEX remains in the remaining LNAPL. Even if this occurs, eventually (i.e., the timeframe cannot be predicted) benzene would likely dissolve out of the LNAPL.

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Commented [WU22]: Some discussion of this in the March 2017 BCT call slides (Mar 2017 BCT presentation.pdf; Slide 26ff.

Also in the:

Response to EPA Review Comments for the Draft Addendum #2 RD/RA Work Plan – Site ST012, p 11.

RESPONSE TO ADEQ COMMENTS DATED 11 FEBRUARY 2016
DRAFT ADDENDUM #2
REMEDIAL DESIGN AND REMEDIAL ACTION WORK PLAN FOR OPERABLE UNIT 2
REVISED GROUNDWATER REMEDY, SITE ST012
FORMER WILLIAMS AFB, MESA, ARIZONA
pages 4-7

Addendum #2 Remedial Design and Remedial Action Work Plan – Site ST012
Lines 744-795
Page 3-5 to Page 3-6

Commented [WU23]: Not sure about this "15 years". The initial plan was EBR for 1.5 years, and then 15 years of MNA?

Commented [WU24]: Probably need more explanation here. What practical problems does this cause for remedy implementation, and meeting remedial goals and timeframes?

Also our modeler could mention the model's use of the same effective porosity values in very different subsurface media, and how that affects the modeling output.

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Path Forward

In order to go forward with EBR, the Agencies propose that a phased implementation approach be employed. The ultimate objective of using a phased implementation is to gather the information ~~we~~ needed to ensure that EBR is being implemented in an optimal manner. From this information, we can establish milestones and criteria against which we can compare the full scale implementation to ensure that the remediation is proceeding in a manner and at a rate that will allow the remedial goals to be achieved in the estimated desired time frame throughout the entire site.

Commented [DE25]: I would really like to use a much stronger word here, like they are required to do a phased implementation, but that is for the managers to decide. As a technical person, my advice is to not let EBR go forward as they propose in Addendum #2.

Commented [WU26]:
Perhaps "… the first step in the AMEC-proposed phased implementation approach be application of EBR in limited areas of the site to gather the information necessary to ensure that EBR is applicable to all areas of the site (i.e., high LNAPL/no LNAPL, CZ, UWBZ, LSZ) and is being implemented in an optimal manner…"

Commented [WU27]: **As AF has indicated**, *"The RD/RAWP and Addendum 2 present multiple lines of evidence based on historical data, post TEE data, pre-SEE data and post-SEE data, all of which support the presence and effectiveness of sulfate reduction-based biodegradation at the site. The purpose of phased EBR implementation is to provide for remedy optimization based on robust collection of long-term site-wide site-specific monitoring data showing effectiveness and rates of sulfate reduction-based biodegradation of the COCs. The implementation of sulfate-based EBR and the associated operational monitoring will be used to demonstrate the achievement of project goals within the estimated remedial time frame."* (p20, Response to EPA Review Comments on the Draft Final Addendum #2, RD/RA Work Plan - Site ST012, August 2016)

So AF will certainly say that they are already planning on doing this. What we want, though, is some additional analyses (microbial, etc.), and limited application of EBR (limited to certain areas of the site, before full-scale site-wide EBR is implemented), until AF can show that EBR is applicable (and likely to be successful in the timeframe) to all conditions across the site.

I think that AF will reply that there is really no reason not to go ahead and do EBR sitewide, and then tweak at various site localities based on monitoring data - which they already plan to do, of course. **How will we respond to that to show that application of EBR to only limited areas for the first phase is absolutely necessary to remedy success?**

The "Decision Tree" states that the first step in implementing EBR would be "To establish location is ready for EBR injections". During this pumping/LNAPL removal and temperature stabilization step, Amec should provide well-documented case studies of specific sites where EBR, as Amec plans to do it, has actually remediated 100s of thousands of gallons of LNAPL/BTEX so as to reach 500-600 ug/L BTEX in groundwater, with no LNAPL remaining (or, at least, no LNAPL with COCs in the LNAPL). At the same time, laboratory experiments should be performed:

a) In light of the inconclusive results from the field test on benzene degradation accompanying sulfate utilization, the first objective of the site specific testing should be demonstrating that the sulfate-reducing microbial consortia at this site is capable of degrading benzene, and if so, what conditions are necessary to maximize the degradation rate. If these laboratory experiments show that benzene degraders are not naturally present, it may be necessary to incorporate bioaugmentation into the EBR work plan. Also, if benzene degradation is found to be delayed until TEX and other compounds are degraded, the effect of this delay on remedial timeframes and plume extent must be assessed.

b) Laboratory experiments could determine if the existing microbial systems at the varying areas of the site (high LNAPL, etc.) ~~is~~are deficient in sulfate, and if so, the amount of sulfate needed to maximize degradation rates, and the amount of sulfate required for degradation of BTEX.

~~b)~~c) As temperatures now vary widely across the site, lab experiments should also evaluate impact of temperature variability on microbial populations. Laboratory testing could determine the optimal temperature for EBR and evaluate degradation rates at different temperatures.

Commented [WU28]: Not sure why this documentation requirement, or the lab studies, should be tied to "To establish location is ready for EBR injections".

Maybe we could say it this way: While AMEC is installing equipment in preparation for EBR injection, AMEC can proceed with the laboratory studies, and providing documentation of previous success with EBR at comparable locations.

Of course AMEC has already admitted that they have not in fact done EBR at comparable locations, and no one else has either. So I'm not sure how far we are going to get with requiring this documentation. I did ask for it, but I haven't seen any such documentation either, and I don't think they can provide it.

Maybe we could indicate that this application of EBR under the site conditions partakes of the nature of a research project, since no one has ever done this before. Therefore it is prudent to require more testing (i.e., our initial phase requirements of lab/microbial analyses, and limited application of EBR across representative areas of the site) before full-scale EBR sitewide. As I added above: "…so the proposed EBR application must involve more extensive data collection and field testing before implementation of EBR at full scale.."

I don't recommend actually saying "research", though. It's just lab and field testing, not a university research project.

Commented [WU29]: AF is going to argue that they have already done this with their modeling, and data from the literature.

Addendum #2 Remedial Design and Remedial Action Work Plan - Site ST012; APPENDIX E Microbial Kinetics Estimation: Michaelis-Menten kinetic parameters and Lineweaver-Burk method, etc.

Commented [K30]: Carolyn's comment.

These laboratory experiments must be performed utilizing soil samples from all four of the hydrologic zones: cobble zone (CZ), UWBZ, low permeability zone (LPZ), and LSZ.

Based on what is learned from the laboratory experiments, the first phase of the field implementation can be designed that will allow determination of benzene degradation in each of the hydrologic zones. Again, all four hydrologic zones should be targeted, ~~as well as~~including areas of heavy LNAPL saturation~~,~~ and areas only affected by dissolved contaminants. Benzene degradation rates can be estimated using a flow-through field setup rather than a push-pull test as was used in the field pilot test. Estimates of benzene degradation derived from the field test can be used in an appropriate predictive model to estimate treatment times, although it must be kept in mind that, "***Anaerobic bioremediation is still not thoroughly understood, especially under field conditions, making clean-up times difficult to predict***" (ESTCP, 1999). The presence of significant LNAPL at this site and low permeability zones that are known to contain LNAPL will limit the biodegradation rate (ESTCP, 1999, page 6). More details on the laboratory and first phase of the field implementation are provided below.

Laboratory Work

These tests would provide a baseline with which to compare data on microbial populations during implementation, as well as assessing benzene degradation and the effects of adding sulfate.

Eleanor (& Dan) – can you fill this in?

First Phase Field Implementation ~~**I've imported what Dan provided previously – needs re-writing**~~

Commented [WU31]: Eleanor indicated that she was preparing this.

From: Eleanor Jennings [mailto:ejennings@teci.pro]
Sent: Thursday, March 09, 2017 4:09 PM
To: Dan Pope; Davis, Eva; d'Almeida, Carolyn K.; Wayne Miller; Steve Willis
Subject: RE: justification for lab and field tests

OK. I'm putting together my own (and much, much more detailed) ideas of what needs to be done before any EBR pilot study, and why.

Commented [WU32]: And needs incorporation of what others have indicated about representative zones, etc.

For example, from Carolyn:

- *Incorporate phased implementation in specified areas differentiating between heavy LNAPL areas and dissolved phase areas in LSZ,UWBZ and CZ 3-6 months should be sufficient to evaluate degradation rate in dissolved phase areas, up to a year to evaluate degradation rate in heavy LNAPL areas Will need observation wells spaced within 6 months travel time of injection wells; bromide tracer useful for evaluating flow distribution around well.*

Evaluate whether sulfate and tracer reach observation wells, then whether amendment is achieving biodegradation or not

- *Update model to verify remedial timeframe, performance evaluation criteria and optimize full scale implementation*
- *Grid the full treatment area into optimization zones based upon existing conditions identified during characterization: Heavy LNAPL vs dissolved phase, temperature, microbial population, available sulfate, etc for optimized treatment, including possible bioaugmentation*
- *Install or designate observation wells within gridded optimization zones to evaluate remedy progress*

Commented [K33]: I'll take a stab at some edits....

~~ask for a field study~~For example, the initial field implementation ~~that involves actually remediating an LNAPL mass – pick a~~should include a well in each zone with substantial LNAPL (i.e., > 2 inches to as much as 5 feet)~~,~~. ~~put a~~The test could be implemented using ~~transect of~~ injection wells upgradient of the LNAPL wells, and a transect of monitoring wells ~~immediately~~ approximately 3 to 6 months of travel time downgradient of the LNAPL well~~,~~. ~~and inject s~~Sulfate and a tracer~~, etc.,~~ should be injected as planned for the full-scale EBR – or as found to be optimal based on lab tests~~?~~. If the ~~AF can timely remediate that well so that~~ no LNAPL is found in the LNAPL wells, water quality parameters indicate reducing conditions, and the COC concentrations in that well and the downgradient monitoring transect are below cleanup standards, then that would be strong evidence that a full-scale approach could work.

~~The chosen LNAPL well should have significant LNAPL – more than a sheen – at least two inches of LNAPL fairly consistently, so that actual *remediation of LNAPL* can be assessed.~~

> ~~Note that my sense of where AF is going is that eventually they will claim that they don't actually have to get rid of LNAPL, but merely get GW concentrations of BTEX down to MCLs, "eventually". Encapsulation of LNAPL by microbial films (to degrade the BTEX moving from LNAPL to GW), by iron sulfide precipitates (to reduce flux of BTEX from LNAPL to GW), fouling and precipitates in and around LNAPL bodies (so that GW doesn't really flow close to the LNAPL) are things that could cause GW concentrations of BTEX to fall, while much BTEX remains in the remaining LNAPL. Hence my continued insistence on the idea that the details of performance monitoring make a huge difference in what "success" is.~~

Chosen wells ~~should~~ could be at elevated temperatures, as long as laboratory testing indicates that EBR is effective at those temperatures, to correspond with the general site conditions.

~~Reagent injections (sulfate, etc.) should reflect those concentrations, rates, volumes, etc. that are proposed for full-scale EBR or as found to be optimal based on lab tests?.~~

Assuming the ~~field study~~first step phased implementaiton continues for at least a year, performance monitoring should be conducted to monitor the changes around the injection, LNAPL, and monitoring wells in terms of microbiology, sulfate concentrations, sulfide production, hydrogen sulfide generation, precipitation of iron sulfides, possible aquifer plugging, changes in pH, oxidation-reduction potential (ORP), etc.~~, can be monitored and~~ The resulting data should be evaluated ~~for~~ to assess viability of a full-scale remedy, and any likely dangers, showstoppers, etc.

Fouling should be assessed for all wells (injection, LNAPL, monitoring), to determine the likely needs for well reworking, refurbishing, eventual replacement, etc. This is particularly important for the follow-on contractor (after AMEC's contract expires) to have an idea of long-term costs, and how to bid. Also, corrosion of carbon steel wells should be assessed, as it is well known in the oil industry that sulfate reduction and the production of H2S accelerates corrosion.

Commented [WU34]: Note that AF intends to get the COCs down to 500-600 ug/L so that MNA can complete the remediation to MCLs in the required timeframe.

Of course that means that the MNA part is also significantly uncertain (i.e., a whole different bag of uncertainty), even if EBR performs just like AF models it.

Commented [DE35]: The decision tree states that <5 ft/week accumulation in wells is non-inhibiting to starting EBR – I think that has to be the standard

Commented [WU36]: AF has consistently denied EBR is planned for LNAPL source remediation, and consistently affirmed that indeed EBR will remediate LNAPL source materials. But if AF is not going back to SEE (or other actual source remediation technology – "actual" meaning in a few years, not some indefinite long-term "eventually"), then EBR has to remediate the LNAPL, and do it right away with minimum hiccups. So the field study should explicitly confirm that a significant mass of LNAPL has indeed been remediated (or not).

Commented [K37]: I worked much of this into a concern.

The downgradient monitoring transect ~~can not only~~should be utilized to monitor COC changes, ~~but also~~and to assess the geochemical footprint of downgradient locations, which would be pertinent to evaluating possible enlargement of a sulfate/etc. plume at full scale.

Also, the distribution and concentrations of sulfate achieved downgradient of the injection transect is of great interest. The AF model indicates ~~they can get~~that a reasonable ~~(to them)~~ sulfate distribution, but ~~reality in~~ subsurface environments ~~is often different~~often vary from ~~the~~ models. The ~~field study~~first phase implementation should be designed to provide suitable data to design injection well spacing, injection rates, injection concentrations, pressures, etc., so as to achieve useful sulfate concentrations across the site.

~~If AF can timely remediate that well so that the COC GW concentrations in those representative wells and the downgradient monitoring wells are (and remain over time) below EBR goals, then that would be strong evidence that a full-scale approach could work.~~

Commented [K38]: Stated earlier.